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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re application of:

Nilo FAGIOLINI et al.

Serial No. 09/423,746

Filed: November 15, 1999

For: REACTIVE POWDER COMPOSITION
AND METHOD FOR PURIFYING GAS

Art Unit: 1754

Examiner: T. Vanoy

Atty. Docket No. 32232-152197

Customer No.



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SUPPLEMENTAL BRIEF

Assistant Commissioner for Patents
Washington, D.C. 22031

Sir:

The SUPPLEMENTAL BRIEF is filed in response to Paper No. 29. In Paper 29, the Examiner required augmentation of the Appeal Brief filed Dec. 2, 2002

- 1) to insert a reference to the drawings
- 2) to insert positive indication of that Claim 3 had been cancelled "in the 116 Amendment date-stamped Sept. 18 2002, and the "Status of the Claims" and "issues" portion of the appeal brief"
- 3) to correct Claims 6 and 13; and
- 4) to refile an IDS.

The Supplemental Brief is filed in triplicate and concurrently with an IDS [as requested by the Examiner and discussed below] and an Amendment.

Moreover, in Paper No. 29, the Examiner has asserted against Claim 13 a ground of rejection under 35 U.S.C. 103 which had been lodged against claims 1, 2, 4-12 [over German Patent No. DE 4100645 (Regler) taken with WO 95/19835]; please see page 6 of Paper No. 17.

The additional grounds of rejection of Claim 13 and items 1)-3) is addressed in this paper. The references filed on October 1 and twice on December 2 2002 are presented under separate cover letter with the heading INFORMATION DISCLOSURE STATEMENT.

In Paper No. 29, the Examiner indicated a 3-month shortened Statutory period from the 1/16/03 mail date of Paper No. 29 for filing a SUPPLEMENTAL BRIEF.

The SUPPLEMENTAL BRIEF is presented within the spirit of the MPEP Section 1208. Brief fees were previously submitted, according to the file in the undersigned office.

References relied upon by the applicants during prosecution are attached hereto, including copies of

Kirk Othmer Encyclopedia of Chemical Technology, Fourth Edition, volume 22, Wiley Interscience Publication, p.276. [1997], including copyright page.

a page of Terence Allen's book entitled "Particle size Measurement", Second Edition, published by Chapman and Hall Ltd.(1975)[Enclosure 1] and

a copy of a page from Ullmann's, Encyclopedia of Industrial Chemistry, Fifth Edition, Vol. A7, p. 160-161, 1986, editor Wolfgang GERHARTZ, publisher:VCH., (Enclosure 2)].

These references were attached to the two responses to the FINAL REJECTION.

REAL PARTY IN INTEREST

The instant application is assigned to SOLVAY S.A.

RELATED APPEALS AND INTERFERENCES

The undersigned is not aware of any appeal or interference which would affect, or be affected by, the outcome of the appeal in this case.

STATUS OF CLAIMS

The claims 1-2, 4-10, 12 and 13 stand finally rejected under 35 U.S.C. §§103 and/or 112 and for obviousness type double patenting. (Claim 3 was cancelled after the Final Rejection.)

STATUS OF AMENDMENTS

The initial Rule 116 September 3, 2002 AMENDMENT was denied entry [PTO Paper no. 21]. Resubmission of the amendment with conformance of the 'clean copy' to the 'marked up version' of amendment of Claim 1 therein resulted in entry of the September 18, 2002 Rule 116 AMENDMENT, as set forth in PTO paper no 24. A paper entitled "**PRESENTATION OF EXCERPT FROM KIRK-OTHMER**" was filed by applicants on October 1, 2002, was refiled with the original Brief, and now per Paper No. 29, is filed with the title INFORMATION DISCLOSURE STATEMENT. Concurrently with this SUPPLEMENTAL BEIF, an AMENDMENT under RULE 116 is presented. (The Amendment proposed is of Claim 13), which proposal is reflected at page 17.

SUMMARY OF THE INVENTION

The invention concerns a solid pulverulent reactive composition based on sodium bicarbonate, for gas purification and scrubbing gases which may contain sulfur oxides and/or hydrogen halides [please see specification at page 1 line 10 et seq.].

The composition comprises

sodium bicarbonate and

a caking inhibitor for sodium bicarbonate;

said inhibitor is selected from the group consisting of lignite coke, a magnesium compound and admixtures thereof, wherein said magnesium compound is selected from the group consisting of magnesium oxide, magnesium hydroxide, mixtures of magnesium oxide and magnesium hydroxide and magnesium hydroxycarbonate;

The composition of the claims is said to be devoid of silica. The invention addresses the problem of agglutination of such compositions, the tendency of the sodium bicarbonate to cake). The inventors have discovered that silica content in such compositions negatively affects the gas cleaning process, in particular when the removal of dust is carried out by means of a filter cloth (Please see the specification at p.5, 1. 24-34). The inventors believe that the silica-free compositions adhere better to the filter cloth than the silica-comprising compositions. The reference to filter clothes relates to means used to remove dust, **i.e. solid waste**, from the gases. Please see page 5 line 15 et seq. of the specification relating to dust removalAccordingly, Claims 1, 12 and 13 recite “devoid of silica”.

Moreover, according to a specially recommended embodiment of the invention composition, which adheres well to such filter cloth, the composition is characterized by a fine mean particle size of less than 50 μ m and a narrow particle size distribution (slope of less than 5) (see description p.3, 1.19 – p.4, 1.4).

Such particle sizes can be obtained by milling commercial sodium bicarbonate (see example 1). Amended claim 1 incorporates the characteristics of particle size: “*said composition exhibiting a mean particle size of less than 50 μ and a particle size slope of less than 5.*” The particular particle sizes of the composition according to new claim 1, in conjunction with the new caking inhibitor and the absence of silica, have proven to be particularly effective, as demonstrated by the examples of the patent application.

Such particle sizes are not those of standard sodium bicarbonate but require additional treatment, for instance milling and sieving, as described in example 1 of the specification at page 8.

Figure 1 and Figure 2 are noted, in view the Examiner's express request at page 3 paragraph 1) of Paper No. 29. Figures 1 and 2, respectively, relate [1] to the array of storage units of compositions of the invention and subsequent testing and [2] to the equipment for, measuring mobility [the ability to flow freely, as described at page 7 line 17 et seq] of the reactive composition of the claims, after storage. Figure 1 illustrates the array of stacking of bag units of the composition. Figure 2 relates to the device comprising a sieve 9, exhibiting a mesh size of 710 μm , positioned above a vertical cylinder 10 with a diameter of 50 μm . Powder is poured through the sieve, collected on top of horizontal face 11 of the cylinder 10 and then the maximum height of the cone of powder measured. According to the parameters of this test, the specification page 7 line 35 et seq. According to this test, the mobility of the powder increases as the height of the cone 12 decreases.

ISSUES

Is Claim 13 unpatentable under 35 U.S.C 112 because of its definition of e.g., D_{50} .

Are Claims 1-2, 4-10, 12 and 13 unpatentable for obviousness type double patenting over Claims 1-14 of U.S. Patent No. 6,171,567 in view of the English translation of DE 41 00 645A1?

Are Claims 1-2, 4-10, 12 and 13 unpatentable under 35 U.S.C. 103(a) as being unpatentable over German Patent Doc., No. DE 41 00 645 A1 to Regler et al in view of WO 95/19835 to Fagiolini?

GROUPING OF CLAIMS

Claim 13 is separately patentable from the remaining claims since it is clear from the various grounds of rejection that the art does not pertain to the recitations in Claim 13.

ARGUMENT

I. Section 112 rejection of CLAIM 13.

In the Final Action, the reason advanced for the rejection of Claim 13 follows:

“Claim 13 is rejected under 35 U.S.C. 112, first paragraph, as containing subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor(s), at the time the application was filed, had possession of the claimed invention. Neither specification on pg. 3 ln. 24 to pg. 4 ln. 4 or in claim 13 explain how D_{90} can represent the diameter at which 90% of the particles have a diameter less than D_{90} . It seems that one would have to know what the D_{90} is on the right side of “represents” in order to determine the D_{90} on the left side of “represents”. A similar rejection is made for the corresponding D_{50} and D_{10} expressions. [Paper No. 17, pages 2-3]

Contrary to the PTO reasons, the expressions are supported, i.e. appear at page 3 lines 19 through page 4 line 4 of the specification; that is, *in haec verbis* support was provided in the U.S. application specification for the expression(s). Specifically, at page 3 line 19 et seq. the specification recites,

In this embodiment of the invention, the mean diameter (D_m) and the particle size slope (σ) are defined by the following relationships:

$$D_m = [\sum n_i \times D_i] / \sum n_i \text{ [sic]}, \quad \sigma = [D_{90} - D_{10}] / D_{50}$$

In which n_i denotes the frequency (by weight) of the particles of diameter D_i , and D_{90} represents the diameter at which 90%... of the particles of the

reactive composition... have a diameter of less than D90..."[specification,pg.4]

Moreover, on page 4 of the specification the appellants indicate the conventional means for making the measurement for particle classification.

Thus, on the strictest reading of Section 112, the PTO position appears inapposite, as both the written description requirement and enablement have been provided by the specification. However, to show on the record that the particle size classification was well within the skill of the art applicants presented various references which speak to particle size classification: Copies of the three references are attached hereto. These references date from 1986, 1975 and 1997.

Those previously submitted references include:

a page of Terence Allen's book entitled "Particle size Measurement", Second Edition, published by Chapman and Hall Ltd.(1975)[Enclosure 1] and
a copy of a page from Ullmann's, Encyclopedia of Industrial Chemistry, Fifth Edition, Vol. A7, p. 160-161, 1986, editor Wolfgang GERHARTZ, publisher:VCH.]

Those two references were attached to the two responses to the FINAL REJECTION. On October 1, 2002 appellants also filed

Kirk Othmer Encyclopedia of Chemical Technology, Fourth Edition, volume 22, Wiley Interscience Publication, p.276. [1997], including copyright page.

Better than an Inventor's declaration, this latter excerpt presents a very clear illustration of the "D90" etc concept: At the top of the page, a very clear cumulative graph is presented. To find, say, D90, you select 90 on the "Y" axis and read the corresponding D90 value on the "X" axis (idem for D50 etc.)

The totality of the references suggests the recitations relating to D90, D50 and D10, would be well within the comprehension of a person of ordinary skill.

In conjunction with this position relating to the person of ordinary skill, the Board may wish to review applicants' Belgian representatives reference to D₅₀, as set forth in Section IIB, below.

Accordingly, reversal of the rejection under 35 U.S.C. 112 is respectfully solicited.

II. The claims are not obvious under 35 U.S.C. 103(a)

A. Claims 1, 2 and 4-12

In Applicants' view, the references commend to the person of Section 103(a) inclusion of a reagent which is expressly eliminated from Claims 1 and 12, from which the remaining claims depend. [As noted in a previous response, PTO policy as expressed in the MPEP, Section 2111.03, the phrase "consisting essentially of" in e.g. appealed Claim 12 is construed to limit the scope of a claim to the specified materials and "those materials that do not materially affect the basic and novel characteristic(s)" of the claimed invention. *In re Herz* (citation omitted).] Elimination of an element suggested in the prior art with improved results in an area unsuggested by the prior art is the epitome of non-obviousness. Please see the cases, *In re Anthony* 64 USPQ 553 at 555-556 (CCPA 1945); *In re Miller* 94 USPQ 88 (CCPA 1952); *In re Fleissner*, 121 USPQ270 (CCPA 1959).

Applicants respectfully traverse the rejections of the claims under 35 U.S.C. 103(a) over German Patent No. DE 4100645 (Regler) which discloses a composition for the purification of gas, taken with WO 95/19835. The title of the Regler reference is "*Waste gas purificn. With nitrogen basic cpds. Removing acid cpds. – by adding ammonia and alkali and/or alkaline*

earth cpds., for foundry, alkali chloride electrolysis, blast furnace, power station, refuse and glass industry.” In general the Regler composition comprises:

- A basic alkaline and /or alkaline earth substance;
- A basic compound comprising nitrogen for absorption of NO_x;
- An additive with large specific area, **including explicitly silica to absorb** certain impurities and improving the reactivity with the gas.

More specifically, the Abstract of the Regler reference recites

“Nitrogen bases (IA) are injected above the dw pt. Of H₂ in addn. to basic alkali and/or alkaline earth cpds. (IB), mixed with the gas stream and reacted and the solids are sepd. In dust separators. Zeolites are used as surfactant (II) together with (IB). Pref. (IA) is NH₃, ammonium salts, e.g. NH₄Cl, urea and/or prim., sec. and/or tert. Amines, (NH₃ gas) (B) is NaOH, KOH, NAHCO₃, Na₂CO₃, KHCO₃, K₂CO₃, quicklime, Ca(OH)₂, limestone, MgO, Mg(OH)₂ and/or MgCO₃, as solid, soln. or suspension. (IB) may be mixed with (II) content of the (IB)/(II) mixt. Is 0.1-95,(0.5-50) esp. 1-10%.”

Applicants respectfully traverse the rejection of Claims 1-10 and 12 under 35 U.S.C. 103(a) as unpatentable over German Patent Doc DE 4100645A1 to Regler [hereinafter ‘Regler’] in view of WO 95/19835.

With respect to the contents of WO 95/19835 [combined with Regler] applicants note that the PTO relies upon it for the English translation of the ABSTRACT. The abstract of this reference suggests that the reactive composition for purifying flue gases comprises sodium bicarbonate and less than 2 wt % of sodium monocarbonate, with a particle size

distribution defined by an average particle diameter of less than 0.05mm. Such disclosure does not make up for the deficiencies of Regler with respect to the appealed Claims.

The differences between Regler and the claims on appeal include the following information:

- Regler's invention lies in the addition of *nitrogen containing compounds, in order to reduce the emission of nitrogen oxides*. This is not the object of applicants' invention to basic alkali and/or alkaline earth compounds; and Regler's invention is not particularly relevant to the object of the invention, which includes solving an agglutination problem, of sodium bicarbonate. Thus, a man skilled in the art who wants to solve an agglutination problem *would not view the Regler's paper at all and the PTO has provided no evidence to the contrary!*
- In applicants' invention the bicarbonate is the main active constituent whereas the magnesium compound is a caking inhibitor *additive*. This is emphasized in originally filed claim 3 [now incorporated into claim 1]. To the contrary, in Regler, the alkaline earth compound can be the main or only (and even *preferred*, see the example) active basic constituent for the gas purification.
- Regler's compositions comprise alkali and/or alkaline earth. The selection of sodium bicarbonate *and* a magnesium compound among 6 alkali and 4 alkaline earth (burned lime, calcium hydroxide, calcium carbonate and magnesium compound) amounts to the selection of two elements among a list of 10 elements, that is one among 90 (10 times 9). **Moreover, Regler recommends adding a surface active substance, including one which is silica.** The probability **avoiding** silica is 4/5, since silica is in a list of 5 elements. In summary, the reconstitution of the constituents of the invention through

multiple selections in the 3 Regler's lists, amounts to a selection of one element in a hundred!

- In order to elicit applicants' invention from Regler, the skilled man would have had, after the selection of one-among a hundred of possibilities, to **modify the proportions** of the selected constituents of the composition. Indeed, in Regler, the magnesium compound is possibly the single candidate of choice as the basic active substance for gas purification. In his only example, Regler discloses a composition consisting of calcium hydroxide only (which is in the same list as the magnesium compounds). By comparison, according to the invention, the magnesium compound is an additive, in proportions of at most 10% in weight!
- The comparison of the applicants' specification examples 7 (in accordance with the invention) and 8 (not in accordance with the invention reveals the particularly interesting advantage of avoiding, according to the invention, the presence of silica. in the reactive composition.
- In conclusion, the Examiner's reasoning is hindsight reconstruction of the Regler invention. The complexity of the selections and modifications needed to reconstitute the claimed subject matter proves that the invention is **nonobvious** over Regler.

The PTO selection from the choices provided by Regler requires applicants' own claimed subject matter as the record here does not establish that Regler's description provides express motivation to exclude silica or an expectation of success. To establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second,

there must be a reasonable expectation of success. Finally, the prior art reference (or references when combined) must teach or suggest all the claim limitations. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art, not in applicant's disclosure. *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991).

Applicants' composition is non obvious for the following reasons:

1. Applicants' invention is intended to solve an agglutination problem (the composition is a caking inhibitor-see claim 1-). **Regler does not mention nor suggest an agglutination problem.** As a consequence, after reading the DE 4100645 document, a person skilled in the art would not make, among Regler's numerous compositions, the very particular selection which solves a problem not even mentioned in the document;
2. In order to reconstitute Applicants' invention from DE 4100645 document, a person skilled in the art must operate successive selections
3. Regler's composition can contain silica (silica is explicitly mentioned among the possible compositions), whereas the Applicants have discovered the negative effect of silica for the agglutination problem. Specifically, Applicants' claims recite that the composition is substantially devoid of silica.

II B. CLAIM 13 IS INDEPENDENTLY PATENTABLE UNDER 35 USC 103(a)

In Paper No. 29, the Examiner has asserted against Claim 13 a ground of rejection under 35 U.S.C. 103 which had been lodged against claims 1,2, 4-12 [over German Patent No. DE 4100645 (Regler) which discloses a composition for the purification of gas, taken with WO 95/19835], but not Claim 13; please see page 6 of Paper No. 17. Applicants traverse and

incorporated by reference the remarks concerning the description of the references above, for the purposes of brevity.

Claim 13 qualifies claim 1 by relating the term "slope" to distributions of particle diameter(s).

Obviousness cannot be predicated on the unknown, as the patent Statute requires the application of "prior art" evidence to support a rejection under 35 U.S.C. 103. Claim 13 is independently patentable of the remaining claims because the Final Rejection relies upon no art which describes the Claim 13 relationship of distribution of particle size diameters, which in turn define the term "slope" in Claim 1. The only comment concerning the patentability of Claim 13 under 35 USC is in the paragraph bridging pages 9 and 10 of Paper No. 29. No differentiation of the terms in Claim 1 vis-à-vis the terms of Claim 13 are noted. No reference is relied upon to show that the qualification of slope is a requirement of a single prior art composition.

The person of ordinary skill would view applicants' claims as suggested by applicants' Belgian representatives, by the following comparison example, in conjunction with the 'median' concept. The median salary of a population is the salary such that half of the people of the population earn more and half of the people earn less than that salary. This is common knowledge. Median salary could be denoted S_{50} . A median diameter is denoted D_{50} and embraces exactly the same concept since it is the diameter at which half of the particles are smaller and half of the particles are bigger.

In applicants' view, the applied art does not describe Claim 13 recitations and does not suggest that requirement of compositions of Claim 13, to a person of ordinary skill. In applicants' view, if a suggestion of granulometry is described in the WO 95/19835 reference as

alleged at page 10 of Paper NO. 29, this alleged suggestion does not 'suggest' claim 13 recitations.

Accordingly, reversal of the rejection of Claim 13 under 35 U.S.C. 103 is respectfully solicited.

Reversal of the rejection under 35 U.S.C. 103(a) is respectfully solicited.

III. The claims are patentable over the "Obviousness-type Double Patenting Rejection.

Applicants respectfully traverse the rejection of claims 1-10, 12 and 13 under the judicially created doctrine of obviousness-type double patenting over claims 1-14 of U.S. patent No. 6171567B1. The question presented by this rejection is: Does citation of the claims of a reference --under 'obviousness type double patenting-- logically pertain to **appealed claims** which **exclude compositions, the use of which**, in accordance with the reference claims, would **infringe the reference claims?**

Applicants' respectfully traverse the obviousness-type double patenting rejection. In applicants' view, the precepts of In re Vogel apply in the instant situation [In re Vogel, 422F2d 438, 164 USPT 619 (CCPA 1970)]; the issue of double patenting present an analysis akin to the determination of infringement, a question of fact. Substantively, applicants note that the discussion above with respect to the non-obviousness of the invention over Regler, also moots the double patenting rejection. In applicants' view combining two references which relate to inventions different from each other and different from the claims at issue does not provide a **prima facie** grounds for double patenting. Evidence of this is that the very composition which applicants' expressly seek to exclude from the claims at issue could be used in a way to infringe the claims of the cited patent [6171567B1].

Legally, applicants' note the Studiengessellschaft Kohle mbH v. Northern Petrochemical Co. [228 USPQ 837 Fed.Cir. 1986] case precedent. In this case, the court held that claims to a product [as claims 1 and 12 in the instant appeal] are not directed to the same invention as claims directed to a process of use, viz., "[B]ecause the two patents claim different statutory classes of subject matter, composition and process, they are not the same invention. Studiengessellschaft Kohle mbH v. Northern Petrochemical Co. [228 USPQ 837, at 840]"

In applicants' view combining two references which relate to inventions different from each other and different from the claims at issue does not provide a prima facie grounds for double patenting. Evidence of this is that the very composition which applicants' expressly seek to exclude from the claims at issue could be used in a way to infringe the claims of the cited patent [6171567B1].

CONCLUSION

Reversal of the three grounds of rejection appears to be in order.

Respectfully submitted,

Date: April 16 2003



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APPENDIX

APPENDIX---CLAIMS

1. Solid pulverulent reactive composition for the purification of a gas, comprising at least 90% by weight of sodium bicarbonate and a caking inhibitor for sodium bicarbonate and being devoid of silica, said inhibitor comprising lignite coke and/or a magnesium compound selected from the group consisting of magnesium oxide, magnesium hydroxide, mixtures of magnesium oxide and magnesium hydroxide and magnesium hydroxycarbonate, wherein said composition exhibiting a mean particle size of less than 50 μm and a particle size slope of less than 5 and wherein said inhibitor is present in an amount by weight of greater than 0.5% of the weight of sodium bicarbonate.

2. (Thrice Amended) The composition according to Claim 1, wherein said magnesium compound is magnesium hydroxycarbonate.

3. The composition according to claim 3, wherein the inhibitor comprises a magnesium compound in an amount by weight at least equal to 2% of the weight of sodium bicarbonate.

4. The composition according to Claim 3, wherein the inhibitor comprises lignite coke in an amount at least equal to 5% of the weight of sodium bicarbonate.

5. A process for the purification of a gas, comprising introducing a reactive composition of Claim 1 into the gas and subjecting the gas to removal of dust.

6. The process according to Claim 6, wherein said subjecting the gas to removal of dust comprises filtrating the gas through a filter cloth.

8. The process according to Claim 6, for the purification of a gas from at least one contaminant selected from the group consisting of hydrogen chloride, hydrogen fluoride, sulfur oxides, nitrogen oxides, dioxins and furans.

9. (Twice amended) The process according to Claim 7, wherein the reactive composition is that of Claim 2.

10. The process according to Claim 1 wherein said silica is one containing less than 0.48% of silica.

12. A non-caking solid pulverulent reactive composition for the purification of a gas containing HC1, HF, sulfur oxide, nitrogen oxide, dioxins, furans, and admixtures thereof, consisting essentially of

sodium bicarbonate and

a caking inhibitor for sodium bicarbonate,

said inhibitor is selected from the group consisting of lignite coke, a magnesium compound and admixtures thereof, wherein said magnesium compound is selected from the group consisting of magnesium oxide, magnesium hydroxide, mixtures of magnesium oxide and magnesium hydroxide, and magnesium hydroxycarbonate;

wherein said composition is devoid of silica.

13. [Proposed] The [process] composition of Claim 1 wherein the particle size slope is defined by σ , wherein

$$\sigma = \frac{D_{90} - D_{10}}{D_{50}}$$

wherein D_{90} represents the diameter at which 90% of the particles of the reactive composition (expressed by weight) have a diameter of less than D_{90} ;

wherein D_{50} represents the diameter at which 50% of the particles of the reactive composition (expressed by weight) have a diameter of less than D_{50} ; and

wherein D_{10} represents the diameter at which 10% of the particles of the reactive composition (expressed by weight) have a diameter of less than D_{10} .

KIRK-OTHMER

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FOURTH EDITION

VOLUME 22

**SILICON COMPOUNDS
TO
SUCCINIC ACID AND SUCCINIC ANHYDRIDE**



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276 SIZE MEASUREMENT OF PARTICLES

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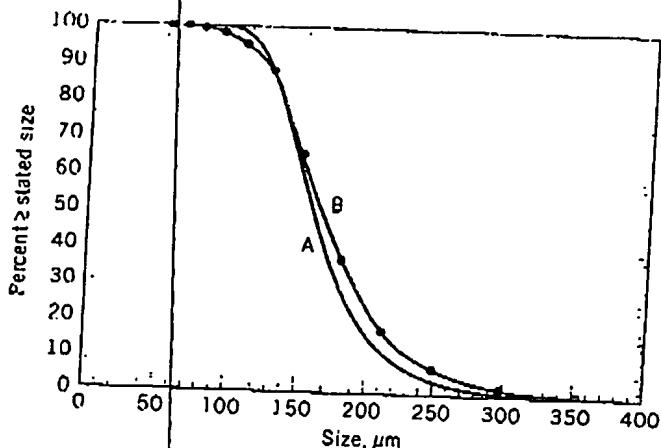


Fig. 15. Size data for a metal powder obtained by A, image analysis, and B, on a diffractometer.

Optical counters have been widely used to monitor cleanroom technology and particles in oil. Instruments manufactured by Royco Inc. (Menlo Park, California) are available for studying aerosols and particles in liquids. The HIAC counter (HIAC Instruments, Monte Claire, California) is a widely used stream counter for particles in fluid. One of the more recently developed optical counters is available from Particle Sizing Systems (Santa Barbara, California). The configuration of one of the widely used counters, the Climet counter, is shown in Figure 16. A general review of photozone counters is available (3).

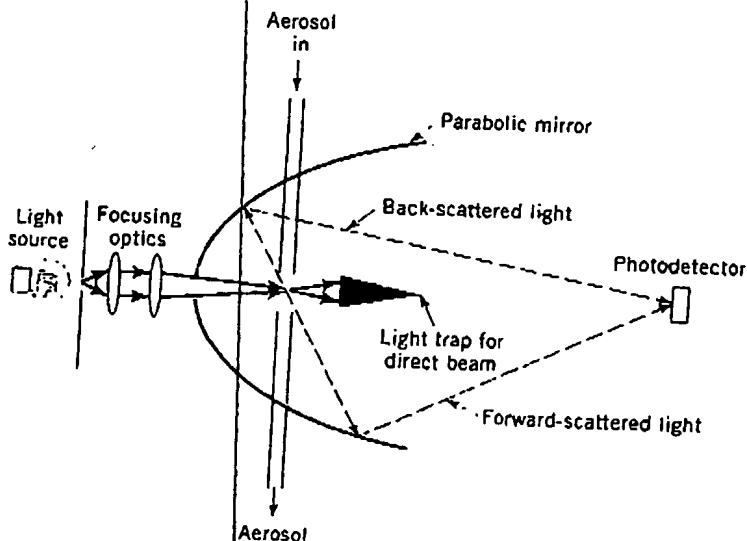


Fig. 16. Schematic representation of the internal structure of a Climet counter.

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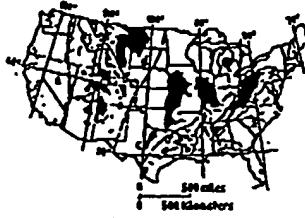
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10 9 8 7 6 5 4 3 2 1

160 Coal



Figure 1. Geographical location of the world's coal.

Figure 2. Coal provinces of the continental United States.
(1) Illinois; (2) Ohio; (3) Indiana; (4) Northern Great Plains;
(5) Pacific Coast; (6) Rocky Mountains

younger, these coals tend to be of lower rank, usually subbituminous, than the Carboniferous coals. Since the Cretaceous some coal has been deposited in scattered lacustrine areas or less continuously and tends to be lignite or brown coal.

The distribution of coal seems throughout the world is also not uniform. As shown in Figure 1, most of the world's coal is located in only three countries, the United States, the Soviet Union, and China. Although the figures vary from source to source, each of these countries has about 25% of the total coal resource, while the rest of the world shares the remaining 25%. In the United States, bituminous coal seams are concentrated in the Appalachians and Illinois Basin. Most of the subbituminous coal occurs in the various smaller basins in the Rocky Mountain region, and the lignite seams are concentrated in the northern Great Plains and the Gulf Coast area.

4. Classification

Coal is combustible and should be composed of more than 20 wt% carbonaceous material [1]. Commercially, coal is classified in a number of ways on the basis of (1) the original plant or material composition, sometimes called coal type; (2) the degree of maturity or metamorphism, called coal rank; (3) the amount of impurities such as ash or sulfur, called coal grade; and (4) the industrial properties such as caking or gasification.

One of the main classifications by composition used by the United States Bureau of Mines is based on the relative amounts of petrographic entities depicted in thin-section analysis, including authigenic (mineral) material, volatile equivalent, or volatile, translucent material (roughly equivalent to lignite), and opaque entities and fossils (roughly equivalent to bituminous) [14, 15]. Under this system, coals are divided into two groups: banded coals, with > 5% authigenic, and unbedded coals, with < 5% authigenic. The banded coals are subdivided into three types: bright coal, containing mainly of authigenic and translucent entities with < 20% opaque matter; semibright coal, containing mainly of translucent and opaque entities with 20–30% opaque matter; and spind coal, containing mainly of opaque entities with > 30% opaque matter. The unbedded coals are divided into several coal, consisting of several with spores, and boghead coal, consisting of entities with algae.

The various banded or layered in coal entities, the so-called layers, have also been classified into five types [14]. These layers appear bright and shiny; dark layers appear as relatively less bright, oxidized layers; bright is dull gray and the charcoal. Although these terms (all coming in *sic*) are not common terms meant to be applied to hand specimen samples, they do have some compositional implications at the microscopic level. For example, bright layers contain mainly spherulitic material, dark layers contain mainly intercristalline material, and charcoal and charcoal are associated with all three mineral types.

The most important classification for commercial purposes in the United States is the ASTM classification by rank. It is the basis on which most of the coal in the United States is bought and sold. This classification, ASTM Standard D 388 shown in Table 1, divides coal

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Table 3. Classification of coal by rank^a

Rank	Group	Fixed carbon series, % (dry, mineral- matter-free basis)	Volatile matter, series basis, % (dry, min- eral-matter- free basis)	Calorific value series, Btu/lb (min- eral-matter-free basis) ^b	Gas-forming character
Anthracite	petrographic	≥ 75	≤ 12	≥ 12,000	non- gas-forming
	carbonaceous	≥ 73	≤ 24	≥ 12,000	
	subanthracite ^c	≥ 72	≤ 24	≥ 12,000	
Bituminous	low-volatile bituminous coal	≥ 75	≤ 34	≥ 12,000	gas-forming but not high-volatile
	medium-volatile bituminous coal	≥ 75	≤ 32	≥ 12,000	
	high-volatile C bituminous coal	≥ 75	≤ 31	≥ 12,000	
Subbituminous	A and subbituminous A coal	—	—	≥ 10,000	gas-forming but not high-volatile
	B and subbituminous B coal	—	—	≥ 10,000	
	C and subbituminous C coal	—	—	≥ 10,000	
Lignite	Spindle A and Boghead B	—	—	≥ 8,000	gas-forming

^aThis classification does not include low coal, principally lignocellulosic material, which have unusual physical and chemical properties and which come within the limits of fixed carbon or volatile values of the high-volatile bituminous and subbituminous ranks. All of these coal other coals < 4% dry, mineral-matter-free fixed carbon or have > 12,000 Btu/lb moist, mineral-matter-free.

^bMake note to coal containing the specified minimum moisture per cent including volatile water on the ashless of the coal.

^cIf a coal containing the specified minimum moisture per cent including volatile water on the ashless of the bituminous class, the moisture content of the coal must be on the dry, mineral-matter-free basis shall be classified according to fixed carbon, moisture of ashless, and rank.

^dIt is recognized that there may be gas-forming varieties in these groups of the bituminous class, and there are notable exceptions to high-volatile C bituminous group.

into 4 classes, anthracite, bituminous, subbituminous, and lignite, which are further subdivided into 13 groups on the basis of fixed carbon and volatile matter content, calorific value, and gas-forming character. The fixed carbon and volatile matter values are on a dry, mineral-matter-free basis and the calorific values are on a moist, mineral-matter-free basis. In this system, coals with ≥ 65% fixed carbon are classified by fixed carbon content and those with < 65% fixed carbon are classified by calorific value. Thus, all lignite and subbituminous coals and the low-volatile bituminous coals are classified by their calorific value. It is also important to note that all coals can be fitted into this system. This is especially true of coals with a high lignitic matter content, such as coked and boghead types.

The other important classification system is the International system of the ISO. In this system, coals are divided into two types: hard coals and lignites, those with calorific values less than that amount. In the hard coal classification shown in Table 4, the coals are divided

into classes, groups, and subgroups. The classes are similar to ASTM groups and based on dry, ash-free volatile matter (p. 260) and moist, ash-free calorific value.

The classes are numbered 0 to 9. The classes are divided into four groups, numbered 0 to 3 on the basis of the swelling properties (free-swelling index (p. 246), also called crucible swelling number, and Rignit index). These groups are further broken down into six subgroups numbered 0–5 on the basis of their Anthracite-Arm classification number and Gray-King coke type. The system is set up in such a way that all coals are classified with a three-digit number, in which the first digit is the class, the second digit is the group, and the third digit is the subgroup.

The lignite and brown coals are only divided into classes and groups. The classes, numbered from 1 to 6, are based on ash-free moisture; the groups, based on dry, ash-free volatile, are numbered from 0 to 4. This classification is shown in Table 5 (p. 161).

Although the ASTM and International Systems are different, there is a reasonable cor-